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PERSPECTIVES ON SOLIDIFICATION/STABILIZATION TECHNOLOGY FOR TREATING HAZARDOUS WASTE

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ABSTRACT

In hazardous waste management, solidification/stabilization (S/S) is a term normally used to designate a technology employing additives to alter hazardous waste to reduce the mobility of pollutants, thereby making it acceptable for current land disposal requirements. The use of this technology to treat hazardous waste may become more important as regulations restrict the use of land for disposing of hazardous waste. This paper discusses the technology and provides information to help assess its potential role in managing hazardous waste. Technical and regulatory factors affecting its use are presented.

INTRODUCTION

Disposal to the land has been the major technology used to manage the country's waste materials. Favorable economics, regulations, and convenience are major factors which enhanced the use of land disposal. However, the Resource Conservation and Recovery Act (RCRA) and the more recent Hazardous and Solid Waste Amendments (HSWA) have provided incentives and controls to encourage treatment and reduce the use of land for managing hazardous waste. Regulations require minimum technology standards for designing and operating hazardous waste land disposal facilities. These standards are more strict than earlier ones and therefore increase the costs. The regulations ban the disposal of free liquids into landfills and are also banning selected wastes from land disposal. These factors are favoring the use of technologies other than land disposal for waste management. However, in order to implement this legislation, the Agency must determine the acceptability of alternatives to land disposal. It must also determine that any treated waste is acceptable for land disposal before it can be disposed to the land.

Many technologies being considered for treating hazardous waste may produce residues still requiring management. In many cases, land disposal will be the only option available for these residues which may contain concentrated toxic contaminants. In addition, before waste can be banned from land disposal, it must be manageable by an environmentally acceptable alternative technology. If it is not, land disposal may still be the only option available. In this case, pretreatment of the banned waste may help make it more acceptable for land disposal.

S/S is being considered as an alternative technology available for treating selected banned waste. It is also being considered for treating residues from other alternative treatment technologies. S/S technology has been used for approximately 20 years to manage industrial waste. The technology employs selected materials (e.g., portland cement, fly ash, lime, etc.), to alter the physical and chemical characteristics of the waste stream prior to disposal on the land. For economic and related reasons, a processor has normally produced an S/S product which will meet only minimum requirements. These minimum requirements are being changed because they may not have been adequately protecting the environment.

The purpose of this session of the Hazardous Materials Management Conference (HAZMAT/West) is to consider the research which may yield new techniques for managing hazardous waste. S/S is not new but is being looked at in a different context. The technology may assume a very important role in treating hazardous waste as the U.S. Environmental Protection Agency (USEPA) proceeds with implementing the waste banning legislation.

Technical and regulatory factors ultimately will determine how useful S/S will be as an alternative treatment technology. Whether or not S/S processes offer effective alternative treatment will depend upon the capability of processors to design their processes to meet more stringent performance requirements which may result from changing regulatory factors.

This paper describes the technology and discusses some of the factors important in determining its usefulness as an alternative treatment technology.

DESCRIBING S/S TECHNOLOGY

Definitions

Definitions for S/S technology vary depending upon the source. In very general terms, S/S, as it relates to managing hazardous waste, refers to a technology which uses additives to transform the waste into a more manageable form or less toxic form by physically and/or chemically immobilizing the waste constituents. Whatever the source, it is important to understand the terminology being used in order to properly evaluate the technology for potential application.

The following definitions are used in this paper:

- Solidification - A process in which materials are added to the waste to produce a solid is referred to as solidification. It may or may not involve a chemical bonding between the toxic contaminant and the additive.

- Stabilization - Stabilization refers to a process by which a waste is converted to a more chemically stable form. The term includes solidification, but also includes use of a chemical reaction to transform the toxic component to a new non-toxic compound or substance. Biological processes, however, are not considered.

- Chemical fixation - Chemical fixation implies the transformation of toxic contaminants to a new non-toxic form. The term has been misused to describe processes which did not involve chemical bonding of the contaminant to the binder.

- Encapsulation - Encapsulation is a process involving the complete coating or enclosure of a toxic particle or waste agglomerate with a new substance, e.g., the S/S additive or binder. Microencapsulation is the encapsulation of individual particles. Macroencapsulation is the encapsulation of an agglomeration of waste particles or microencapsulated materials.

- Binders - Binder systems can be placed into two broad categories, inorganic or organic. Most inorganic binding systems in use include varying combinations of hydraulic cements, lime, pozzolans, gypsum, and silicates. Organic binders used or experimented with include epoxy, polyesters, asphalt/bitumen, polyolefins (primarily polyethylene and polyethylene-polybutadiene), and urea-formaldehyde. Combinations of inorganic and organic binder systems have been used. These include diatomaceous earth with cement and polystyrene; polyurethane and cement, and polymer gels with silicate and lime cement.

Process Types

Several S/S processing schemes available for consideration include:

- In Drum Processing - In this process, the S/S binders are added to the waste contained in a drum or other container. After mixing and setting, the waste - binder matrix is normally disposed of in the drum.

- In-Plant Processing - In plant processing refers to a plant and/or process specifically designed for solidification/stabilization of bulk waste material. This may be a process conducted within a plant to manage the waste from an internal industrial operation or may be a plant specifically designed and operated to solidify/stabilize waste from external sources.

- Mobile Plant Processing - Mobile plant processing refers to S/S processes and equipment which either are mobile or can be easily transported from and set up site to site.

- In-situ Processing - The addition of binders directly to a lagoon or the injection of solidifying or stabilizing materials to the soil subsurface, etc., to promote the solidification/stabilization of the contaminated sludge and/or soil is referred to as in-situ processing.

Objectives of S/S Technology

The broad objective of S/S technology is to contain a waste and prevent it from entering the environment. In practice this broad objective may be realized by several mechanisms which lead to factors important in assessing S/S technology. These are:

- producing a solid
- improving the handling characteristics of the waste
- decreasing the surface area across which the transport of the contaminant may occur, and
- limiting the solubility of the contaminant when exposed to leaching fluids

Idealistically, the objective is to completely transform the potentially toxic contaminant into a non-toxic form. This objective implies chemical transformation and formation of new compounds. Realistically, chemical changes of the contaminant do not routinely occur with available state-of-the-art S/S technologies.

WILL S/S BE AN EFFECTIVE ALTERNATIVE TECHNOLOGY?

There are technical and regulatory factors which will ultimately dictate the use of S/S as an alternative treatment technology. A review of Table 1 helps put this in perspective. Current regulatory requirements for S/S concern the free liquids in landfill ban and delisting. The Paint Filter Liquids Test (PFLT) is the acceptance criteria for the former, while the Extraction Procedure (EP)/Modified Extraction Procedure (MEP), in conjunction with other specific factors, is the acceptance criteria for the latter. This will most likely change as the proposed Toxicity Characteristics Leaching Procedure (TCLP) develops, and as acceptable alternative treatments are defined as the land disposal restrictions proceed.

Problems with use of S/S at CERCLA sites primarily involve technical rather than regulatory issues associated with inhomogeneity of waste, location conditions, unusual safety requirements, etc. Inhomogeneity of waste streams and in-situ contamination will be the largest technical obstacles to S/S at CERCLA sites.

Whether or not S/S becomes an important alternative treatment technology ultimately depends upon regulatory requirements and the capability of the technology to meet these requirements. In order for it to be effective, vendors may need to implement technical improvements to their processes to meet more severe performance criteria.

Technical Considerations

The most important technical needs involve developing a scientific understanding of the S/S processes. In order for S/S technology to be effective in managing hazardous waste, it is critical that process candidates be properly selected, formulated, and used. There are several factors important in the selection and subsequent performance of candidate processes. These include waste chemical and physical characteristics, binder physical and chemical characteristics, interactions of binder/waste and impurities in the matrix, product placement regime, and others. Knowledge of these factors and the interactions which can be expected among the various candidate binders and waste types is critical to the successful use and evaluation of S/S for managing hazardous waste, and therefore its role as an alternative treatment technology.

TABLE 1. APPLICATION, OBJECTIVES AND CRITERIA for SOLIDIFICATION/STABILIZATION

	RCRA Waste	CERCLA Waste
APPLICATIONS:	° Solidify liquid waste for deposit in landfills ° Treat banned waste ° Treat residues from alternative treatment technologies	° On-site in-situ contamination ° On-site containerized waste ° Mobile processes ° On-site treatment for removal

	Level I	Level II	Level III
TREATMENT: OBJECTIVES	° No liquids in landfill - bulk liquids - containerized liquids	° Prepare waste for land disposal - place into hazardous waste disposal facility	° Delisting - place waste into non-hazardous disposal facility
REGULATORY STDS and/or CRITERIA	° Paint Filter Liquids Test (PFLT) ° 50 psi unconfined compressive strength test (if needed)	° No liquids requirement ° If waste hazardous, S/S waste is still hazardous ° New requirement?	° MEP/TCLP + Constituents ° New requirements?
POTENTIAL PROBLEMS/ ISSUES:	° Realistic criteria? ° Predicting performance - no STD tests ° Physical sorption - will liquids (organics) flow by gravity ° Long term durability ° Chemical reaction requirement	° Realistic criteria? ° predicting performance - no STD tests ° Long term durability (physical-chemical) ° Best leaching procedure ° Placement requirements	° Realistic criteria? ° Predicting performance ° Best test procedures (physical-chemical) ° Long term durability ° Chemical vs. physical bonding ° Placement requirements

Studies are required to determine the long-term physical-chemical stability of S/S residues when placed on the land. Studies also are required to determine how and under what conditions S/S residues should be placed in order to ensure environmental protection over the long term.

Prediction and measurement of the performance of S/S processes and products is an area of concern. Performance requirements may vary depending upon the treatment objective that processors are attempting to meet. (See Table 1.) There are regulatory criteria such as the PFLT, the EP/MEP, and/or the emerging TCLP. Data is needed to provide a correlation between regulatory criteria and the real world situations. An example is the TCLP requirement of the relatively small particle sizes for leaching in the test versus the monolithic structure of many S/S products as placed in the field. Physical properties (e.g., strength, structural integrity, etc.) currently are not a significant factor in the regulatory performance criteria. These, however, are probably a critical factor in acceptable long-term durability and chemical performance of S/S products.

This area needs to be more fully investigated. Current efforts have begun to evaluate effectiveness of several protocols to characterize S/S products. This work needs to be extended to provide effective measurement techniques. More important, however, research needs to correlate results of such tests with prediction of performance in the field. This will become more important as regulatory requirements for landfilling and delisting become more stringent.

Superfund site cleanups which may consider S/S technology will be faced with how to implement in-situ processes, equipment needs, and waste inhomogeneity, and how to evaluate effectiveness of S/S. Drummed waste should be similar to RCRA waste, except for having less control over homogeneity of the waste. In the case of in-situ contamination (e.g., soil, ponds, etc.), additional factors must be considered. Protocols will be required on how to determine or evaluate the effectiveness of processes and equipment to effectively solidify/stabilize the contaminated soil and/or lagoon. Proper mixing of the contaminated soil and binders is a key factor. Protocols are required to evaluate mixing efficiency and resulting solidified/stabilized soil performance at varying soil depths. Personnel safety will also be important.

Generally, it is recognized that S/S technology is effective for inorganic waste. Organic wastes generally cause problems resulting in poor S/S. More information is required on the amounts of organic compounds that can be included in inorganic waste streams without requiring pretreatment prior to S/S or which will not adversely affect the S/S product performance. This is especially important because expected waste streams and/or residues are likely to be highly contaminated with organics. Long-term effects of organics on S/S are important and currently little is known.

Although S/S is a candidate alternative treatment for waste banned from landfilling, it is anticipated that its major role will be in the treatment of residuals from other alternative treatments. As these residuals are produced, they may contain more concentrated toxics than the original waste. It will be necessary to evaluate S/S processes to determine their ability to effectively treat these residuals. Information is required to correlate initial chemical and physical characteristics of the S/S waste with long-term performance. This will aid development of more accurate predictions of long-term performance of S/S products when placed on the land. Such information will be required in order to develop adequate technology standards for S/S of selected wastes.

Regulatory Considerations

This area is addressed in this paper only from the standpoint of pointing out problem areas which may arise. The research must provide data to either support the adequacy of regulatory tests (EP, TCLP, Paint Filter Liquid Test, etc.) and similar provisions or to offer recommendations for changes. One area of concern is the inability of regulatory procedures, e.g., EP and TCLP, to appropriately test specialized S/S techniques. Microencapsulated wastes that have been macroencapsulated with high density polyethylene, for example, should be leached or otherwise tested as an intact unit mass because this is the basis for their performance. Regulatory procedures provide only for grinding or crushing wastes before testing. This technique may be applicable to routine S/S techniques but it does not test the potential of specialized S/S techniques for providing superior performance, particularly when extremely concentrated toxics are being treated.

SUMMARY AND CONCLUSIONS

This paper discusses the potential role that solidification/stabilization may have as an alternative treatment technology. The technology is described, definitions are provided, and areas requiring attention are discussed. Whether or not SS is an effective alternative technology greatly depends upon two factors. These are the regulatory criteria which S/S will have to meet and whether or not vendors of the technology are able to use existing processes or develop new processes to meet more stringent regulatory requirements.